SORENSEN
POWER SUPPLIES

instruction manual for

QRC SERIES
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SORENSEN COMPANY

A RAYTHEON COMPANY

676 ISLAND POND ROAD MANCHESTER, NEW HAMPSHIRE 03103

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FIVE-YEAR WARRANTY

Sorensen Company warrants all parts of equipment of its manufacture, except special purpose tubes and semi-conductor devices which carry their own manufacturer's warranty, to be free from defects caused by faulty material or poor workmanship. Sorensen Company warrants its products to conform to applicable commercial or military specifications when confirmed on the Order Acknowledgment form to be free from defects caused by faulty material or poor workmanship. Sorensen Company's obligation is limited under the warranty to repair or replacement of products in kind, or at its option to issuance of a credit of original purchase price. Returns must be accompanied by a Sorensen Company Return Material Authorization form and conform to standard conditions for adjustment. The aforesaid warranty shall expire five (5) years following the last day of the month of shipment from Sorensen Company's plant. The foregoing states the entire warranty extended by Sorensen Company. No other warranty, expressed or implied, is made and, specifically, Sorensen Company makes no warranty of merchantability or fitness for any purpose. In no case shall Sorensen Company be liable for any special or consequential damages. Authorization must be obtained prior to return of defective items.

SORENSEN COMPANY

SPECIFICATIONS

ELECTRICAL SPECIFICATIONS:

Model Number	Voltage Range (VDC)	Constant Voltage reg.[1] (line and load combined)	Current range (amps)	Constant Current Reg.	Constant Voltage Ripple[2] (RMS)	Constant Current Ripple (RMS)	Transient Response[3]	Temperature Ambient (°C)	Temperature Coef. MV/°C
QRC20-8A	0-20	±.005% or ±1 mv	0-8	±.05% or ± 4mA	1 mv	2 mA	25 microsec.	−20° to + 50° (to +71°C derate current linearly to 50%)	.01% + .5 mv
QRC20-15A	0-20	±.005% or ±1 mv	0-15	±.05% or ± 8mA	1 mv	4 mA	25 microsec.		.01% + .5 mv
QRC20-30A	0-20	±.005% or ±1 mv	0-30	±.05% or ±16mA	1 mv	8 mA	50 microsec.		.01% + .5 mv
QRC40-4A	0-40	±.005% or ±1 mv	0-4	±.075% or ±3mA	1 mv	1mA	25 microsec.		.01% + .5 mv
QRC40-8A	0-40	±.005% or ±1 mv	0-8	±.05% or ± 4mA	1 mv	2 mA	25 microsec.		.01% + .5 mv
QRC40-15A	0-40	±.005% or ±1 mv	0-15	±.05% or ± 8mA	1 mv	4 mA	25 microsec.		.01% + .5 mv
QRC40-30A	0-40	±.005% or ±1 mv	0-30	±.05% or ±16mA	1 mv	8 mA	50 microsec.		.01% + .5 mv

Notes:
1. For load change (0 to full or full to 0) and ±10% line voltage change combined.
2. Less than 25 mV peak to peak typical.
3. To return to a bandwidth ±X mV for change from 0 load to full load or full load to 0 load. Where X = .02 volts for 40 volt models and .01 volts for 20 volt models.

INPUT VOLTAGE RANGE: 105-125/200-240/210-250 Vac, Single Phase (by input tap change).

INPUT FREQUENCY RANGE: 50-400 Hz. (30 amp models 50-60 Hz)

RESOLUTION (Voltage): 0.01% of Output Voltage maximum.

RESOLUTION (Current): 0.05% of Output Current maximum.

RFI: Meets MIL-I-26600 and MIL-I-6181D.

PARALLEL OPERATION: Up to 4 units may be operated in parallel. (derate current to 90% of maximum)

SERIES OPERATION: QRC units may be operated in series up to a total rated output of 200 volts above ground.

REMOTE SENSING: The output voltage may be regulated at a load point remote from the power supply. Maximum allowable lead drop in negative leg is 3 volts.

STABILITY: 0.025% of E max for 8 hours, after warm-up.

REMOTE PROGRAMMING: VOLTAGE MODE — By Resistance or Voltage Change
OHMS VOLT = 100 (all models)
VOLTS VOLT = 1:1 Caution: External signal source must be floating and able to absorb 10 mA

CURRENT MODE — By Resistance or Voltage Change

$$\text{OHMS/AMP} = \frac{200}{\text{I max.}}$$

EXAMPLE: For QRC20-15A

$$\text{OHMS/AMP} = \frac{200}{15} = 13.33 \text{ ohms}$$

VOLTS/AMP = 0-250 mV for 0 to full load (all models)
Caution: External signal source must be able to absorb 1 mA and must be floating

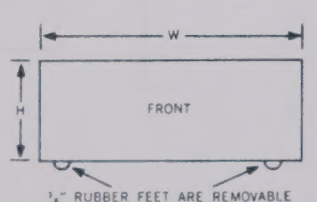
REAR TERMINALS PROVIDED FOR ALL PROGRAMMING MODES.

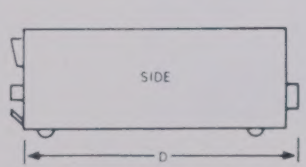
MECHANICAL SPECIFICATIONS:

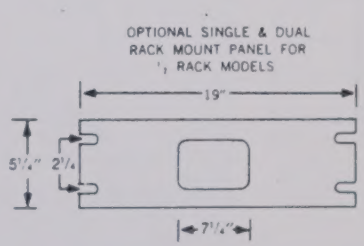
Model Number	Cabinet Outline Detail	Weight (lbs.) Net	Weight (lbs.) Shipping
QRC20-8A	B	36½	60
QRC20-15A	C	54	75
QRC20-30A	D	75	95
QRC40-4A*	A	26	45
QRC40-8A	B	45	65
QRC40-15A	C	67	90
QRC40-30A	D	92	115

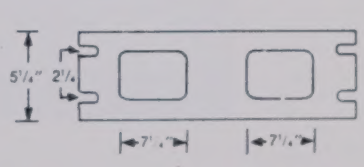
* Half rack

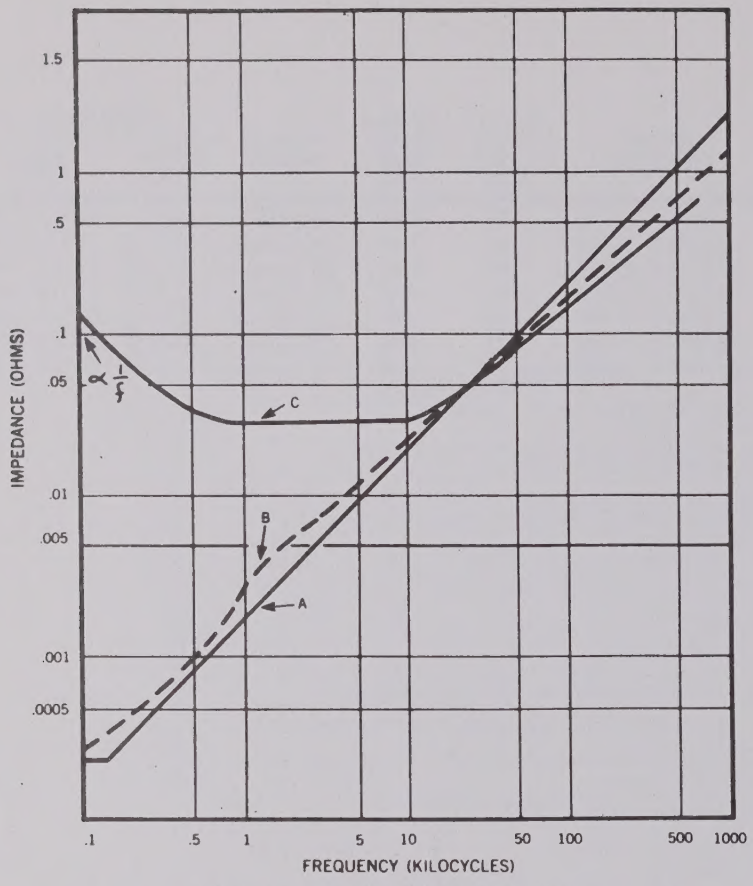
	A	B	C	D
Height	5	3½	5¼	7
Width	8⅛	19	19	19
Depth	16⅛	17¾	18½	18½











OUTPUT IMPEDANCE (QRC40-8)

OUTPUT IMPEDANCE

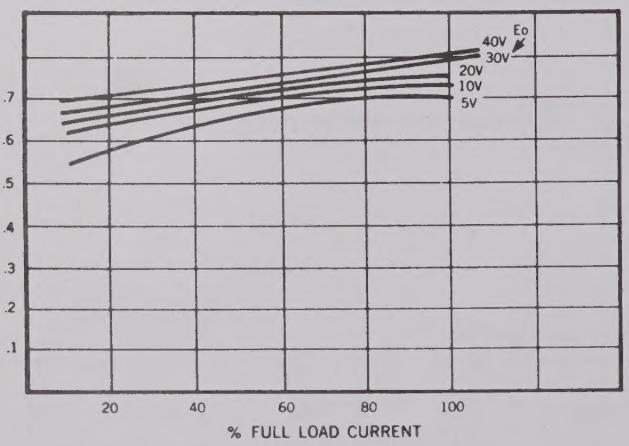
VOLTAGE MODE:

A = Spec. $R + j\omega L$
$R = 2.5 \times 10^{-4}$ OHMS
$L = 0.3 \times 10^{-6}$ HENRIES

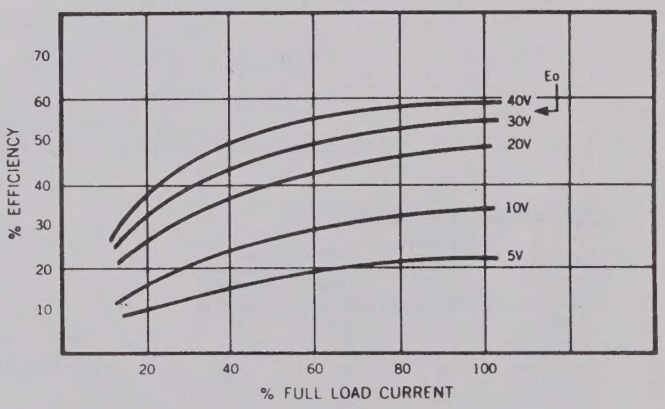
B = Measured Zo (40V @ 8A)

CURRENT MODE:

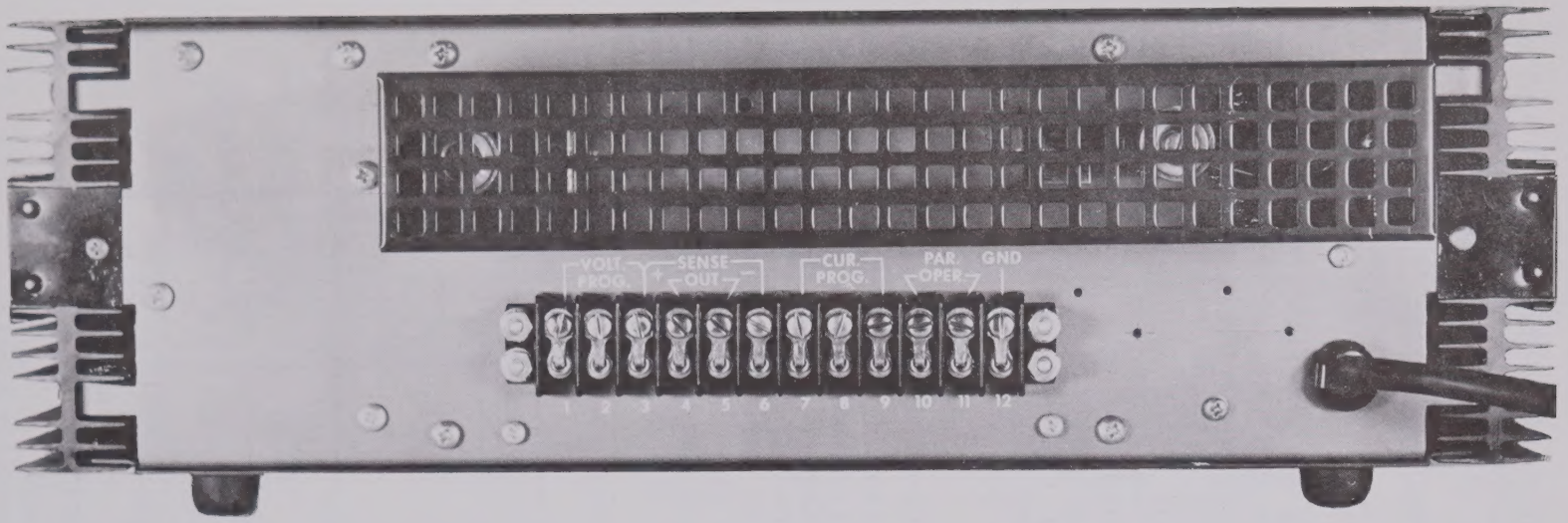
C = Measured Zo in the CURRENT MODE



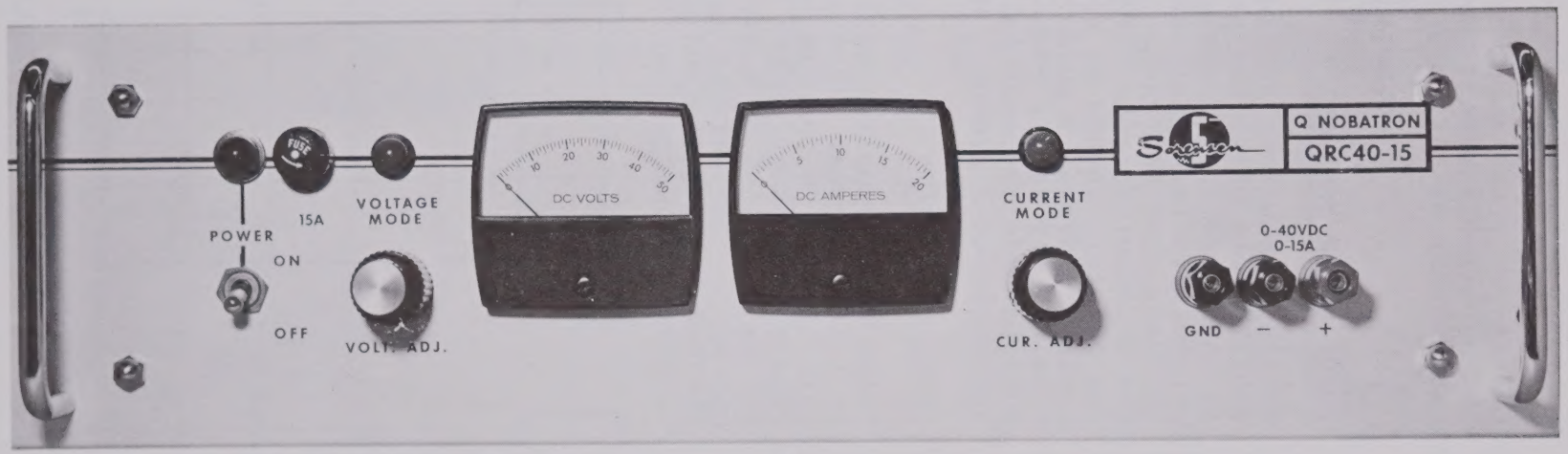
POWER FACTOR (QRC40-8)



TYPICAL EFFICIENCY (QRC40-8)



REAR VIEW OF TYPICAL QRC POWER SUPPLY



FRONT PANEL OF TYPICAL QRC POWER SUPPLY

The QRC Series power supplies are completely self-contained and may be used as bench top instruments or (without any conversion or attachment) may be rack mounted in any standard 19-inch rack.*

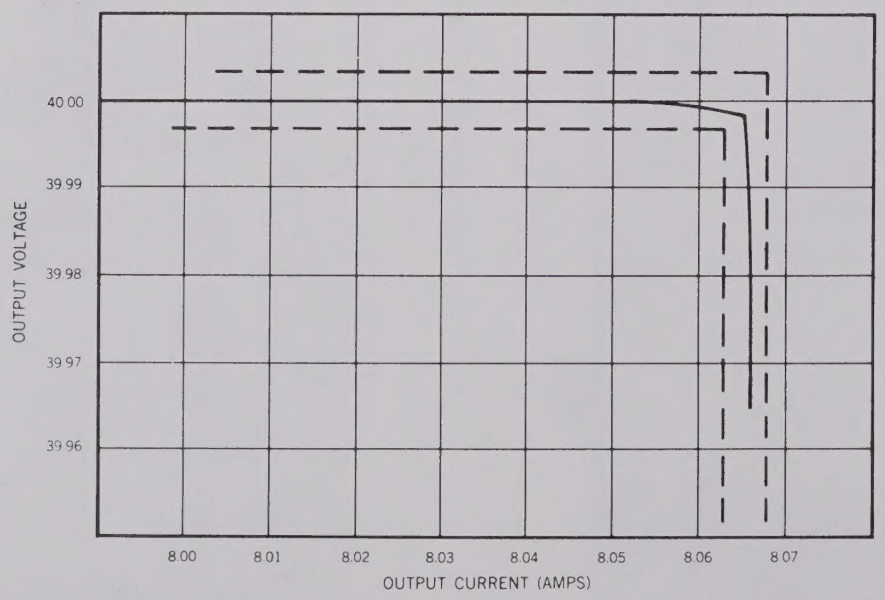
TERMINALS AND CONTROLS

1. INPUT POWER CONNECTIONS

The input power is applied by means of a line cord utilizing a 115/220-volt polarized plug. Since the third prong of this plug is connected to the chassis, connection of the line cord to the appropriate receptacle automatically grounds the equipment. If the user does not have a three-prong outlet available, he should use an adapter. The extra wire (colored green) coming out from the adapter, should be solidly grounded to the power line wiring system, preferably soldered. The aforementioned should be carried out for safety reasons. Input connections for 30-amp unit must be made to input terminal board TB3; terminals 1 and 2 line and terminal 3 ground. See Figure 2.

2. INPUT CONVERSION

These power supplies will operate from either 115, 220 or 230-volt input power. They are generally shipped set up for 115-volt input. To convert to 220 or 230-volt operation refer to Figure 1. Change jumper wires on transformer T1 and resistor R87 as indicated by heavy lines. Be sure to change fuse F1 to one of 1/2 the current rating used for 115-volt input. Models QRC20-30A and QRC40-30A have circuit breakers (CB1) which do not require any change when converting to 220 or 230-volt operation.



TYPICAL CROSSOVER CHARACTERISTIC QRC40-8A

*Model QRC40-4 is a half-rack unit.

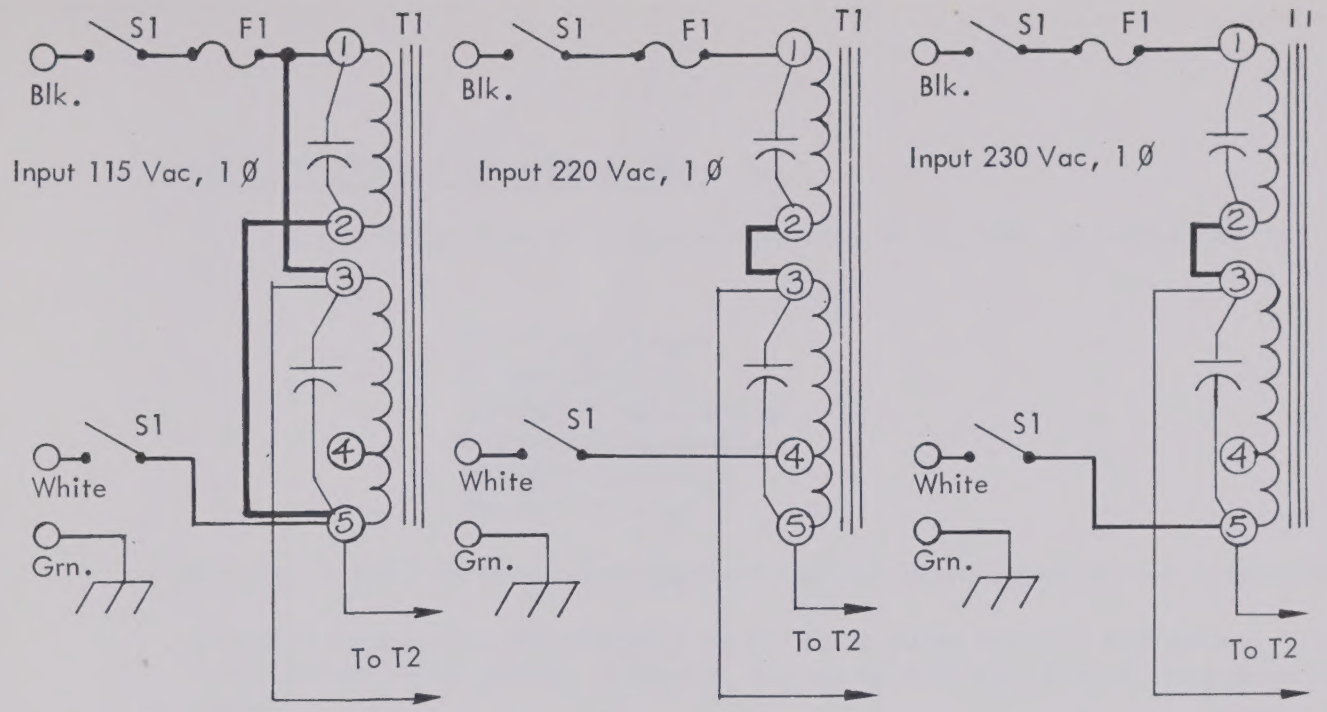


Figure 1a. For all except Models QRC20-30A and QRC40-30A

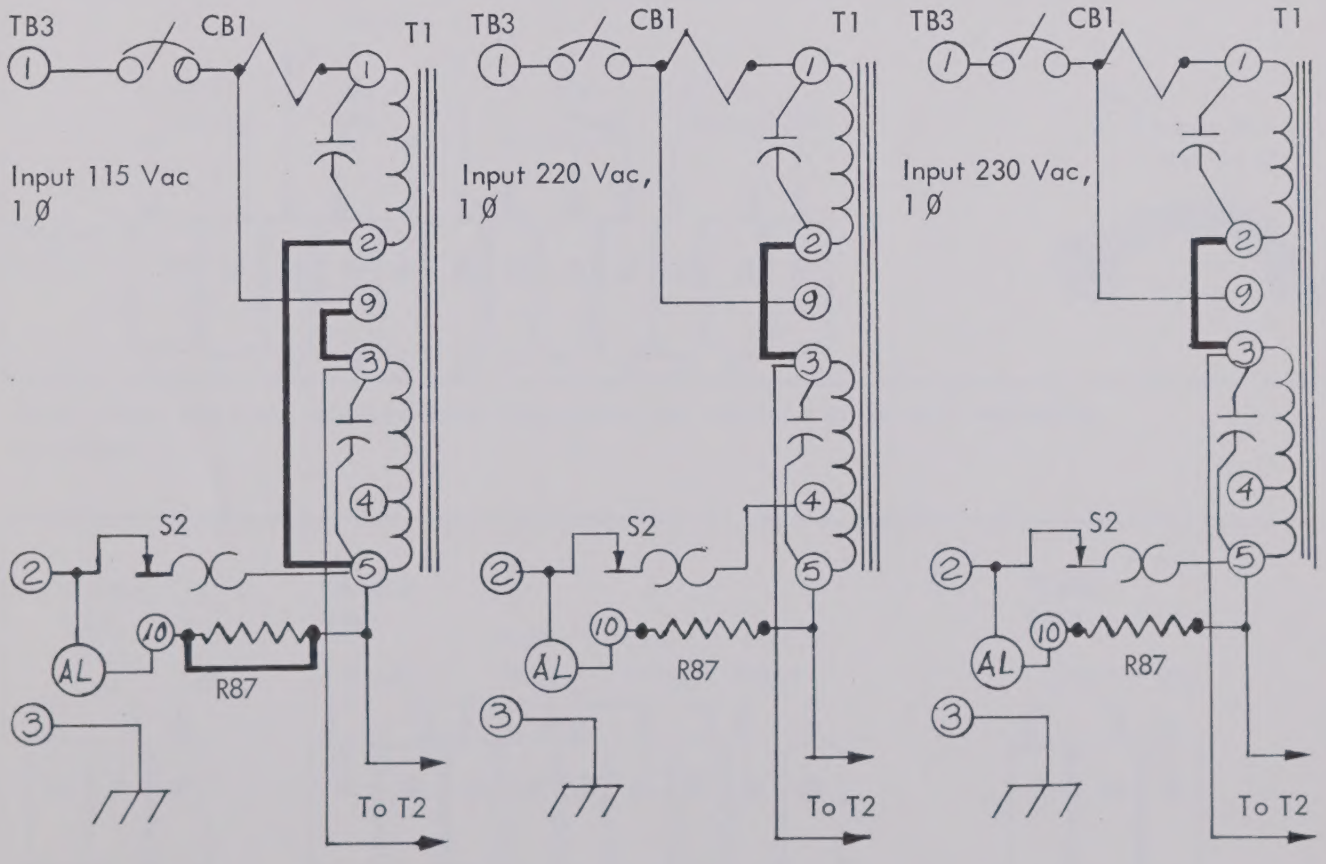


Figure 1b. For Model QRC40-30A only

3. OUTPUT POWER CONNECTIONS

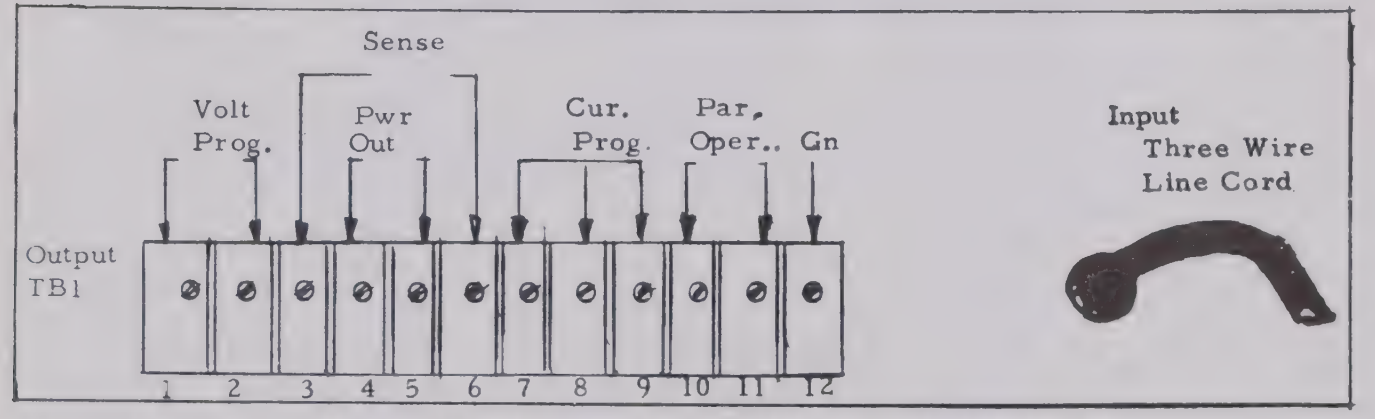
An output terminal board, located at the rear of the unit, provides the following:

DC Power Output
Remote Sensing
Voltage Programming
Current Programming
Parallel Operation
Chassis Ground

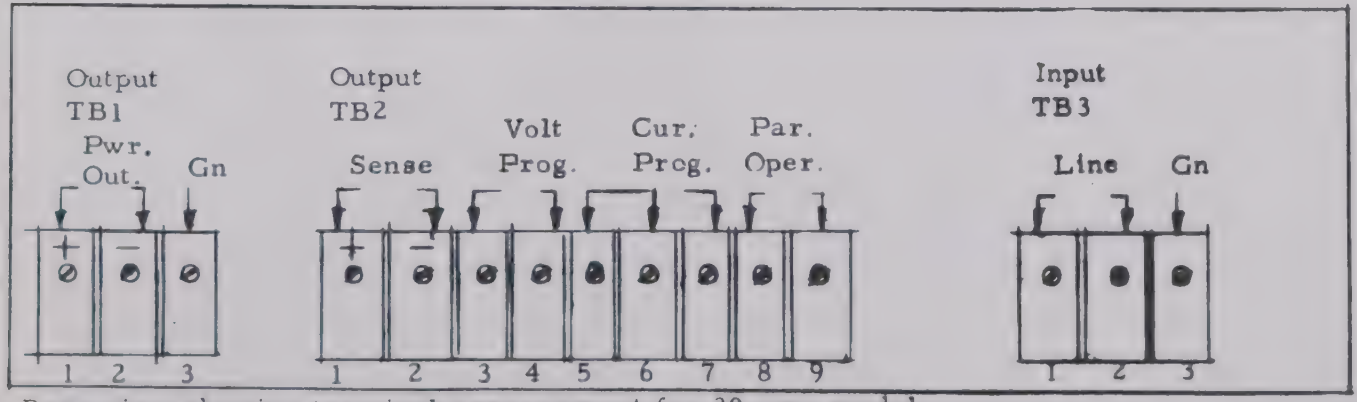
See figure 2 for terminal arrangement and the following pages for procedure.

Output terminals are also located on the front panel for plus and minus output power, and ground. (Except 30 amp models which have rear terminals only).

Figure 2



Rear View showing terminal arrangement for models up to and including 15 amps



Rear view showing terminal arrangement for 30 amp models

4. INPUT POWER SWITCH

A switch S1 located on the left side of the front panel, turns the unit on/off. It connects or disconnects both sides of the input power line. (Except 30 amp models which have a circuit breaker).

5. PANEL LIGHTS

On/Off power indicator
Voltage mode operation
Current mode operation

6. METERS

The DC voltmeter, located on the front panel, monitors the output voltage
The DC ammeter, located on the front panel. monitors the output load current.

7. CONTROLS

Front panel controls consist of coarse and fine output voltage adjustments and coarse and fine output current adjustments.

8. INPUT FUSE

An input fuse (F1) in series with the input power line. is located on the left side of the front panel. (Except 30 amp models which have a circuit breaker).

PARALLEL OPERATION

No more than four (4) units may be connected in parallel. Each unit should be derated to 90% of maximum current. The total current in the parallel operation mode should not exceed 60 amperes.

The connections for parallel operation are shown in Figure 3. Additional slave units may be connected to the master in a like manner to the one slave shown. For terminal board arrangement and terminal number sequence see figure 2.

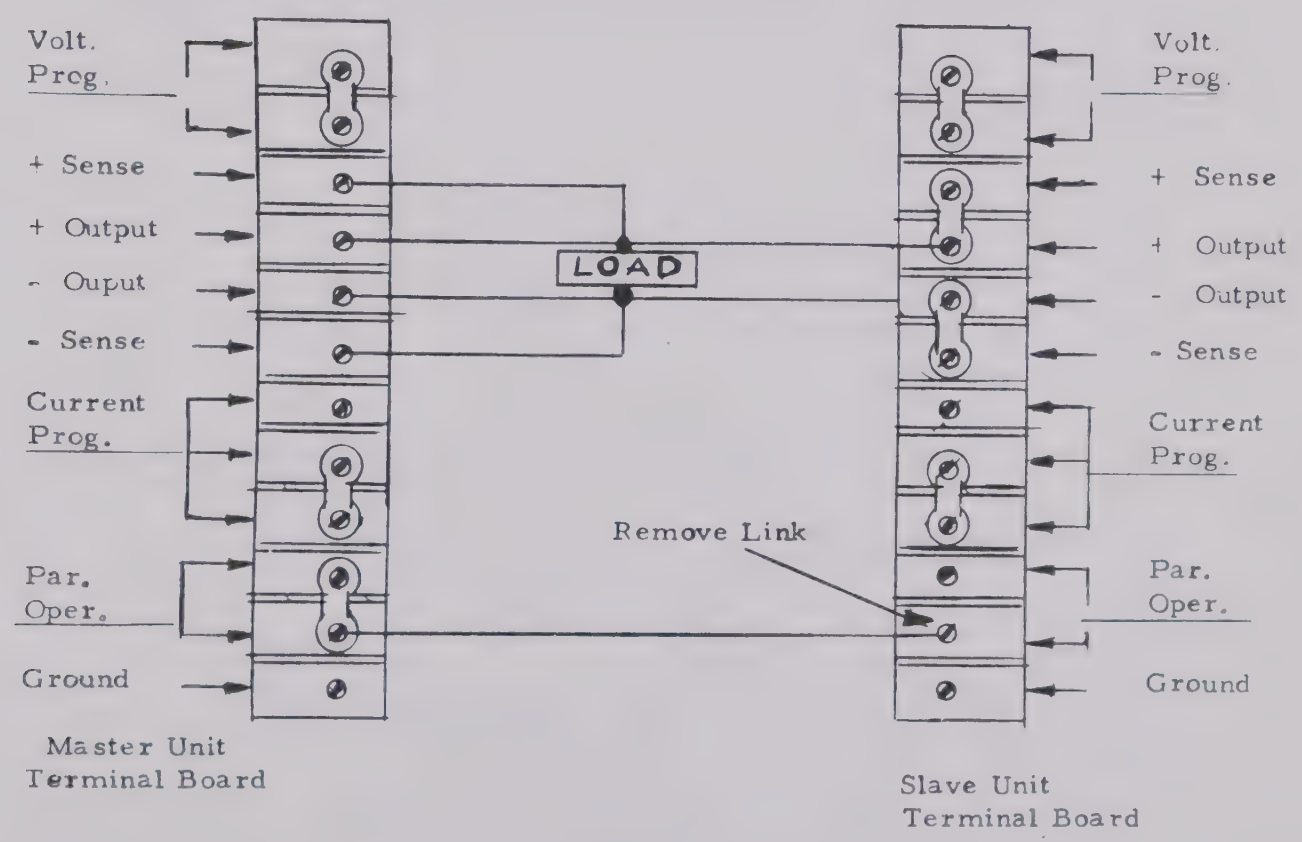


Figure 3

The load connections shown using remote sensing are preferred but not necessary.

SERIES OPERATION

QRC units may be connected in series up to a total rated output of 200 volts above ground. Connections should be as shown in Figure 4. External sensing should be used, as shown, to avoid the effects of load regulation in the interconnecting wires. The rectifiers (CR) are required to prevent the application of negative voltage to the output of any one of the power supplies. Without the rectifiers, negative voltage could result under certain conditions of " turn-on, " turn-off", short circuit or overload, possibly causing damage to the output capacitors. With the rectifiers, the supplies may be turned on and off individually or as a group.*

In series operation, each power supply continues to function as a separate entity. The output of each supply is adjustable, independently of the others. The total regulation is the sum of the regulation of all the supplies. Input connections to the supplies need not be paralleled. For terminal board arrangement and terminal numbers see figure 2.

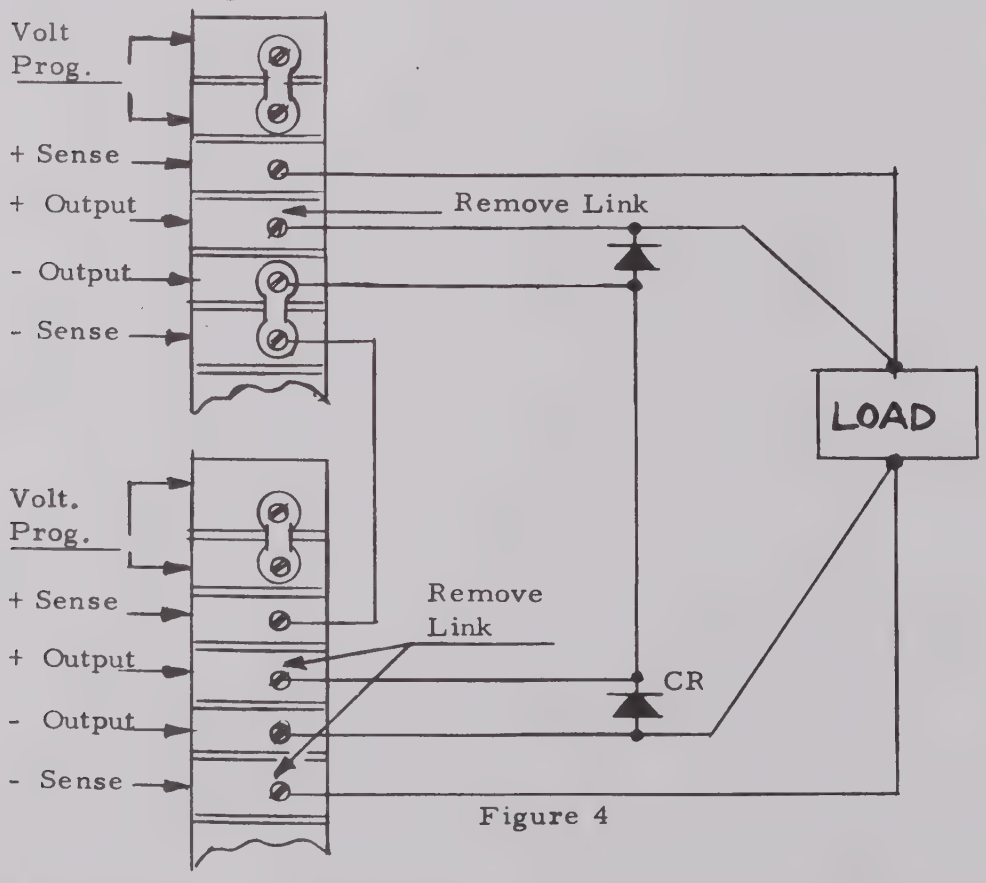


Figure 4

* The current rating of the rectifier CR should equal that of the output rating of the unit.

REMOTE SENSING

The QRC power supplies have provision for regulating the output voltage at a load point remote from the cabinet. This is accomplished by removing the links between " sensing" and " out" terminals then connecting leads from the sensing terminals to the remote load point. See Figure 5. The following precautions should be observed

1. The sensing leads should be a coaxial pair or twisted pair in order to minimize stray pick-up which might result in instability in the regulator.

2. The power leads must be chosen for a maximum of 3.0 volt drop, in the negative lead.

3. The rated output of the supply applies at the output terminals. Any lead drops must be subtracted from these ratings to determine the capabilities at the remote load.

   For terminal board arrangement and terminal numbers see Figure 2.

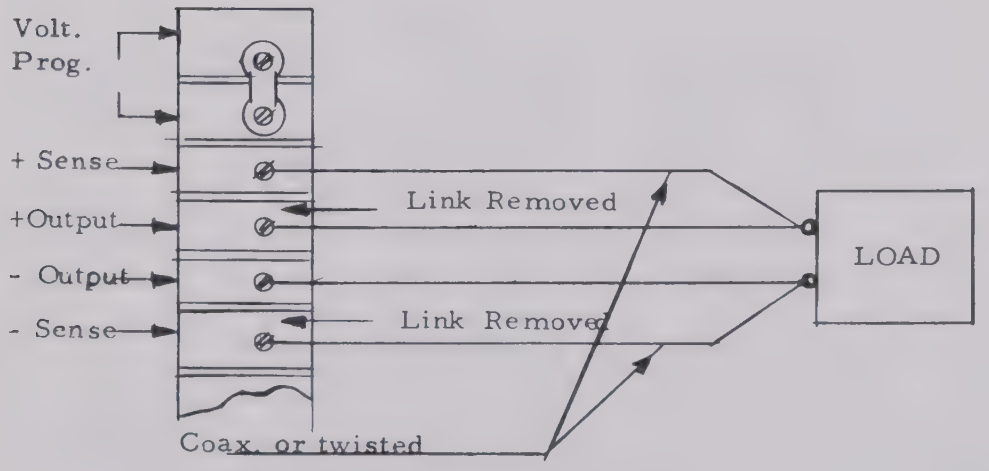


Figure 5

Model QRC series power supplies have provision for programming of the output voltage or current by resistance.

VOLTAGE

The approximate ohms per volt for external programming in the voltage mode is 100. The procedure is as follows:

To program the output voltage externally, remove the link from the voltage programming terminals. Connect the proper resistance* for the program between terminals 1 and 3 of TB1 (For 30 amp models terminal board number is TB2).

CAUTION: Never operate the unit with voltage programming terminals " open". When the link is not in place a proper resistance must be across terminals 1 and 3.

CURRENT

The approximate ohms-per-amp for external programming the current mode is as follows:

Model	Ohms per amp
QRC20-8	25
QRC20-15	13.5
QRC20-30	6.7
QRC40-4	50
QRC40-8	25
QRC40-15	13.5
QRC40-30	6.7

The procedure is as follows:

To program the output current externally. remove the link from the current programming terminals. Connect the proper resistance* for the program between terminals 7 and 9 of TB1 (For 30 amp models connect the resistance between terminals 7 and 5 of TB2.

CAUTION: Never operate the unit with current programming terminals " open". When the link is not in place a proper resistance must be across terminals 7 and 5.

* For best operation and stability, the programming resistance should be a low temperature coefficient (± 30 PPM) wire wound resistor (fixed or variable) or it should be maintained in a constant ambient.

IV. PRINCIPLE OF OPERATION

The operation of this power supply can best be understood by referring to the block diagram (Figure 6) below and to the schematic diagram.

THE MAIN POWER CIRCUIT

Input is applied to the input transformer T1. The output of T1 is rectified and filtered (CR1 to CR4 and C2) and applied to the switching stage of the pre-regulator. The control circuit of the pre-regulator consists of a saw-tooth generator, an emitter follower, a Schmitt trigger, a DC amplifier and a switching stage.

SAW TOOTH GENERATOR

The voltage ramp formed by the RC network R3, R4, C4,combined with the discharge action of unijunction transistor Q1, comprise the saw tooth generator. The saw tooth wave developed across C4 is converted by C5 , R5, R6 to a modified saw tooth shape which is fed to the emitter follower (Q2) and resistor R10 which is a mixer block. Q3 and Q4 controls the DC level of the saw tooth signal. Mixed DC and saw tooth signal is used to fire the Schmitt trigger.

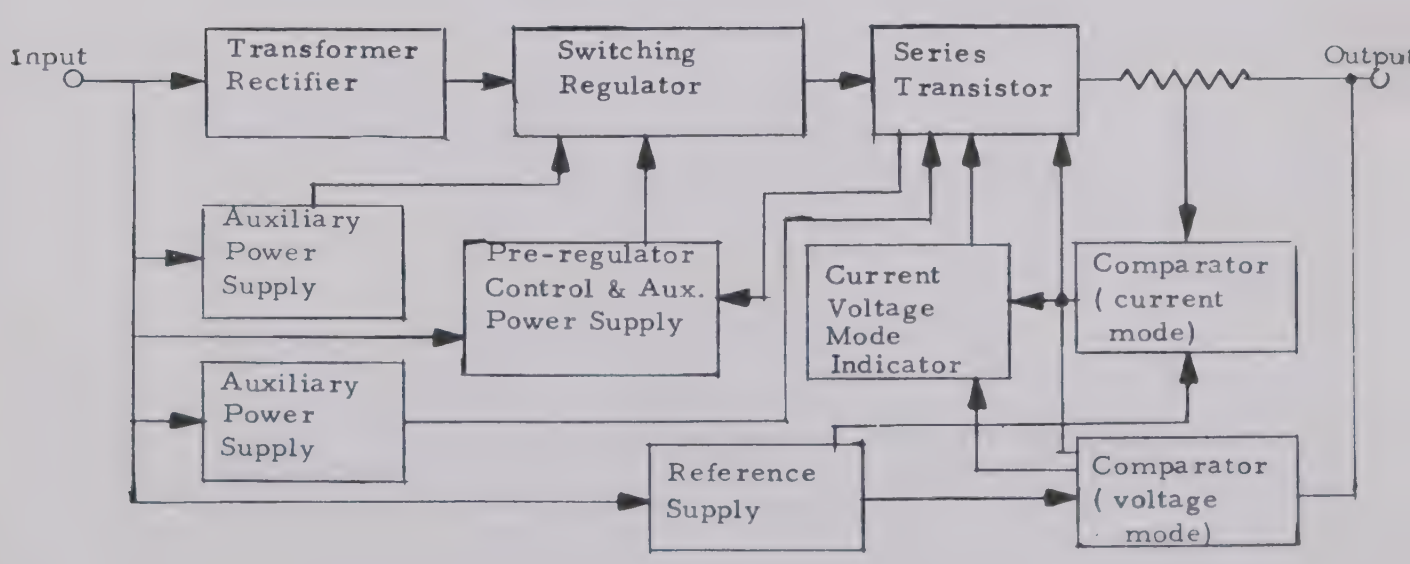


Figure 6

THE SCHMITT TRIGGER

Transistors Q5, Q6, and their associated circuitry form the Schmitt trigger which determines the duty cycle of the pre-regulator. The output of the trigger circuit is amplified by Q7 and Q8 to drive the switching transistor Q11 which is connected in a Darlington circuit with Q9. The drop across the passing stage network (R37, Q13, R52. R39) is the voltage regulated by the pre-regulator.

THE SWITCHING STAGE

The series transistor Q9 is a switch which regulates the DC power supplied to the main regulator. The duty cycle of the pre-regulator controls the on-time and frequency of Q9 which in conjunction with the main filter circuit (L1, C13) maintains a constant 5 volt potential across the series passing stage network.

The configuration Q12, R34, CR15, R35, R36 is a constant current generator which maintains a quasi constant current load on the pre-regulator.

THE MAIN REGULATOR

The main regulator of the power supply uses a three-stage Darlington circuit consisting of driver transistor Q15, amplifier transistor Q14 and series transistor Q13. The series stage is a variable impedance device which is electronically adjusted. The control circuits drive the base of Q13 so that the voltage drop across the series stage corrects for any tendency for change in the output.

The control circuits consist of two amplifier channels. The " voltage mode" channel is a double differential amplifier (Q35, Q36, Q32 and Q33) which senses the output of the power supply and compares it to a reference. The difference voltage is amplified and is used to drive the three-stage Darlington.

THE REFERENCE SUPPLY

One of the secondary windings of transformer T2 (term 4 and 5) supplies operating voltage for the reference source. This voltage is rectified and filtered (CR21, C21) to power the reference supply. The reference supply consists of matched differential amplifier Q25, reference diode CR23, second differential amplifier Q23, Q24, driver transistor Q22 and passing transistor Q21. Transistor Q21 maintains constant 12 volt output of the reference supply.

The reference is sensed at the output terminal # 6 and the junction of R60, R83.

Another secondary winding of T2 (term 6, 7, 8) supplies back bias to the Darlington circuit.

CURRENT REGULATOR

The reference supply generates a second reference source via CR20 and R56. This reference source is used for the current mode channel and for the pre-regulator. The difference between the reference potential at the junction of R53, R54 and the voltage drop across R52 is compared, and amplified in the double differential amplifier Q18, Q19, Q16 Q17. The resulting difference voltage is amplified and is used to drive the three stage Darlington circuit.

CURRENT/VOLTAGE MODE INDICATOR

The current/voltage mode indicator is a completely electronic device for instantly indicating the mode in which the power supply is operating. By observing this indicator the operator will also be able to tell the instant of cross-over from one mode to the other. It is a differential amplifier fed from a constant current source and it drives two indicator lamps located on the front panel.

RELAY K1

Relay K1 is used to rapidly discharge critical networks in case of momentary (millisecond) line failures. This permits nominal operation to resume, following the transient.

V. MAINTENANCE AND REPAIR

During normal life, this instrument requires no maintenance other than the care afforded similar equipment. It is suggested that excessive dust and any other foreign matter be removed periodically exercising care to prevent damage to the instrument by cleaning tools or excessively strong air blasts.

CAUTION: KEEP ALL LINKS TIGHT AT ALL TIMES

Only qualified personnel who understand transistorized regulator circuitry should attempt the repair of this unit. if damage should occur. The following trouble-shooting chart should aid in correcting minor failures.

Major servicing should be done only by the factory or one of its representatives.

Symptom	Probable Cause	Procedure for Repair
1. High output voltage	1a. Shorted switching and/or passing stage	1a. Check switching and passing stages and drivers (Q9, Q11, Q13. Q14 and Q15) replace
	1b. Defective transistor on printed circuit board	1b. Check all transistors Replace* BE SURE TO REPLACE IN PROPER SOCKETS
	1c. Open sensing string	1c. Be sure sensing links and/or connections are all securely fastened.
	1d. Open voltage adjust pot (R59A or R59B)	1d. Check and replace
	1e. Printed circuit board connector not making good contact in socket.	1e. Check all surfaces. Be sure all surfaces are clean and making good contact.
	1f. Auxiliary supply failure	1f. Check all seven DC voltagesindicated in small circles on schematic diagram

* If any potentiometers (other than front panel controls) or any small signal type transistors are replaced, the circuit involved should be realigned. See respective part of alignment procedure.

Symptom	Probable Cause	Procedure for Repair
	1g. R57 defective	1g. Check and replace Re-align circuit
2. Low or no output voltage	2a. No input voltage into main transformer	2a. Check input line connections, main switch (or circuit breaker) and connections on main transformer. Check for proper 115/220 volt setup
	2b. See 1b, 1e, 1f.	2b. See 1b, 1e, 1f.
	2c. Defective Relay	2c. Observe whether relay contacts operate and are clean. Clean or replace.
	2d. Open " parallel operation" terminals	2d. Check and fasten securely
3. No current limiting	3a. Unit faulty in voltage mode	3a. Check voltage mode. See 1 and 2 above for correction
	3b. Loose connection on current programming terminals	3b. Check and fasten securely
	3c. Defective current adjust potentiometer (R53A or R53B)	3c. Check and replace
	3d. Defective potentiometer R50	3d. Check and replace Re-aiign circuit
4. Circuit breaker tripped or fuse blown	4a. Shorted main rectifier (CR1-CR4)	4a. Check and replace
	4b. Shorted switching and passing stages	4b. See 1a
	4c. Shorted C1, C2 or C13	4c. Check and replace

ALIGNMENT PROCEDURE

1. Pre-Regulator Alignment

1.1 Apply nominal input voltage. Connect a frequency counter across C4 and adjust R4 (on printed board) to a frequency of 4000 ± 200 cycles per second.

1.2 Connect an external DC voltmeter between the " output" end of R52 and the junction of R36, R37.

Apply nominal input voltage. Set R57 (on printed board) to indicate approximately 5 volts on the external meter. Set the output voltage to nominal and gradually put full rated load on the output.

Reset R57 to 5.0 ± .1 volts.

If the rated output current cannot be reached, gradually adjust R54 until full rated current is obtained. R54 is located on a bracket adjacent to the printed circuit board.

2. Current Mode Range Adjustment

2.1 Turn both output current panel controls to zero (fully counter-clockwise) Connect a proper external ammeter in the load circuit. Connect a calculated resistance equal to the maximum rated load across the output terminals and apply nominal input voltage. Adjust R50 (on printed board) turning slowly until external ammeter just reads zero.

2.2 Remove the load from the output. Set both output current panel controls to maximum (fully clockwise). Apply load gradually until unit load is within the following load setting.

Model	Load Setting
QRC40-4	4-15-4.25
QRC40-8, QRC20-8	8.3-8.5
QRC40-15, QRC20-15	15.6-16
QRC40-30, QRC20-30	31.2-32.0

Adjust R54 until current mode light goes " off" and then reverse until current mode light just re-appears. (Be sure output current is within load setting shown above).

3. Voltage Programming Alignment

3.1 Set input power switch to " off" and remove output load. Remove link from voltage programming terminals. Connect a precision resistor across the programming terminals as follows:

For QRC 40 volt models use 4000-ohm resistor
For QRC 20 volt models use 2000-ohm resistor

Apply nominal input voltage.

Adjust R69 (located on bracket adjacent to printed board) to obtain the following output voltage:

For QRC 40 volt models - 40 $\pm$ 0.2 volts
For QRC 20 volt models - 20 $\pm$ 0.1 volts

Remove input voltage and disconnect precision resistor from voltage programming terminals. Replace voltage programming link and fasten securely.

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